Development of a Moving Bed Pilot Plant for Thermochemical Energy Storage with CaO/ $Ca(OH)_2$

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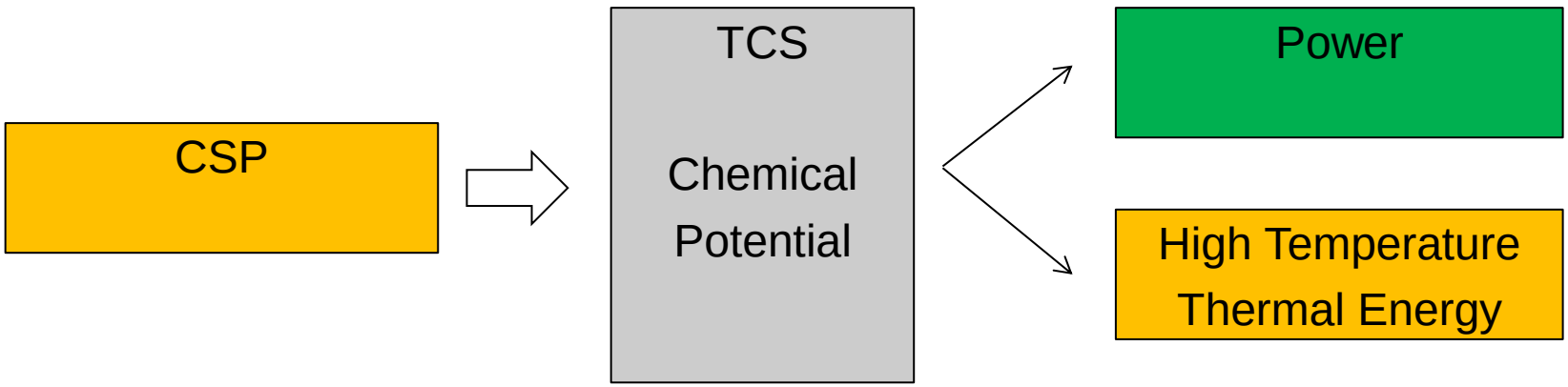
Thermochemical energy storage



Thermochemical Energy Storage

Limestone is a promising storage material

- Environmental friendly and nontoxic
- Production in industrial scale
- Cheap raw material (50€ per ton)
- Additional chemical potential with the reaction with water vapor

Thermochemical Energy Storage

Reaction system CaO/ $Ca(OH)_2$

charging step - endothermal

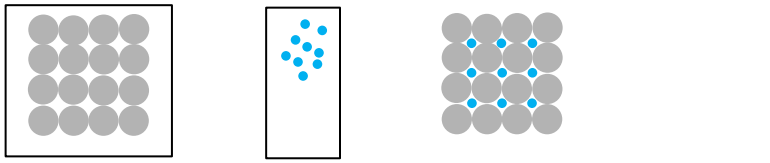
$$CaO_{(s)} + H_2O_{(g)} \rightleftharpoons Ca(OH)_{2(s)} + \Delta H$$

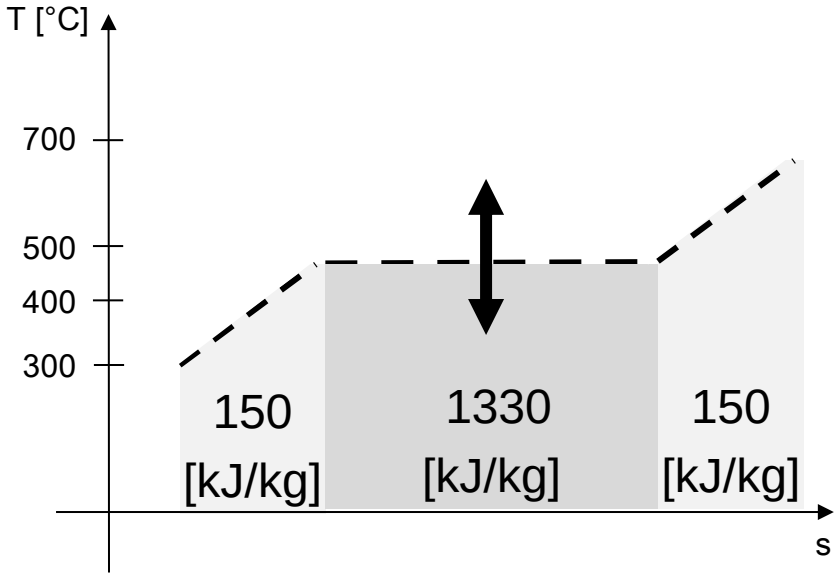
Thermochemical Energy Storage

Reaction system CaO/ $Ca(OH)_2$

discharging storage exothermal

$$CaO_{(s)} + H_2O_{(g)} \rightleftharpoons Ca(OH)_{2(s)} + \Delta H$$





- Very high energy density – 1330 kJ/kg
- Chemically stored energy is free of losses

- Temperature range 400-700°C

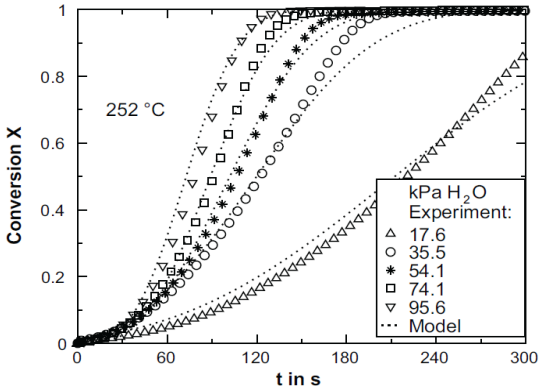
=> Cheap storage capacity cost – 12,5 €ct./kWh

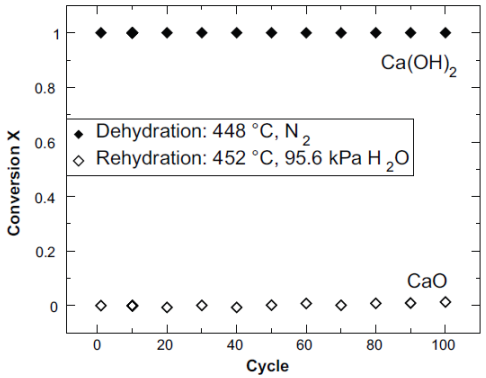
Material properties - CaO/ $Ca(OH)_2$

Chemical properties:

- Fast reaction kinetics

- Cycle stability





F.Schaube et al. (2012).A thermodynamic and kinetic study of the de- and rehydration of $Ca(OH)_2$ at high H_2O partial pressures for thermo-chemical heat storage. Thermochimica Acta 538(2012) 9 - 20

Thermophysical properties:

- Fine powder (d_{50} ~ 5 µm)
- Low permeability
- Low thermal conductivity (0.1 – 0.4 W/mK)

=> Complex reactor/heat exchanger design

Reactor operation

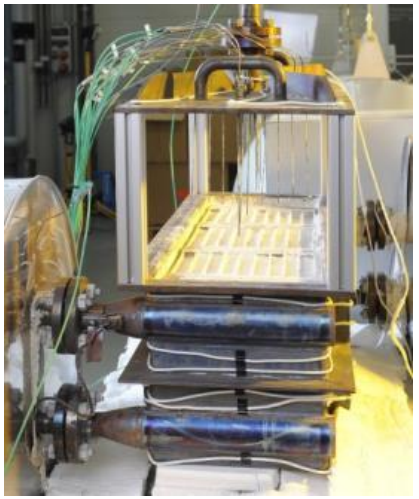
- Indirectly heated fixed bed

- Demonstration of 8kW thermal power

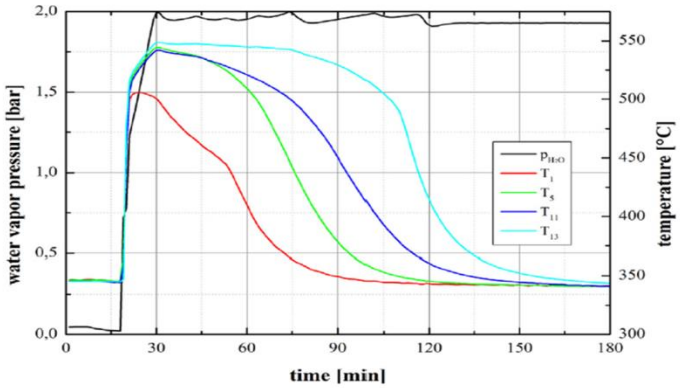
- Capacity of 10kWh (25 kg of Material)

- Charging and discharging at different temperatures through adjustment of vapor partial pressure

=> Upscaling is possible but economically not reasonable

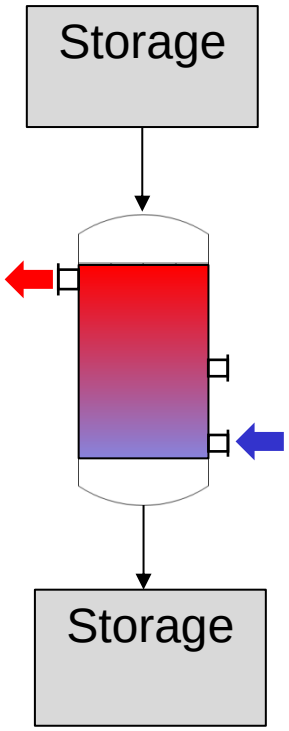


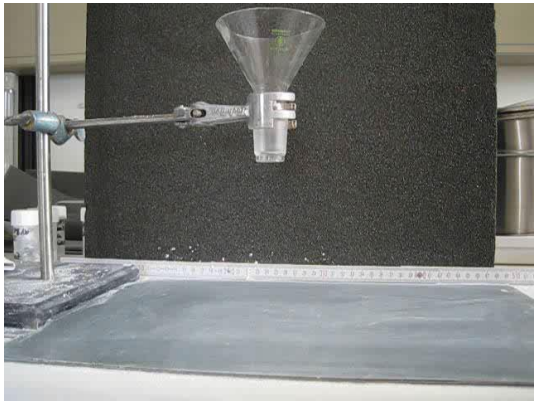
Schmidt et al. (2014) Experimental results of a 10 kW high temperautre thermochemical storage reactor based on calcium hydroxide; Applied Thermal Engineering

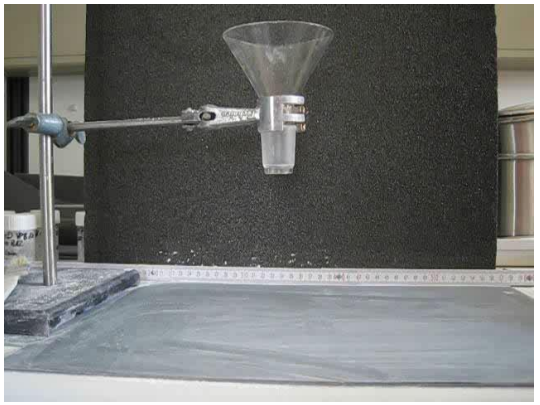


M. Linder et al. Thermochemical energy storage in kW-scale based on CaO/ $Ca(OH)_2$. Energy Procedia, 42, 888-897, 2014

Detachement of power and capacity

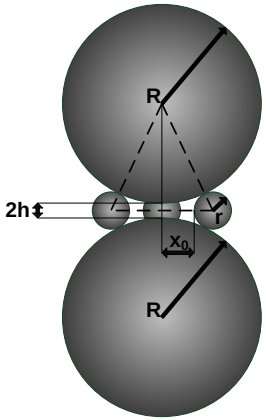


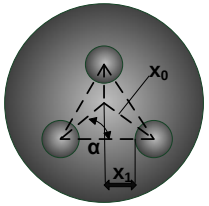




- Coating of $Ca(OH)_2$ by addition of nano particles

-Increased distance between particles



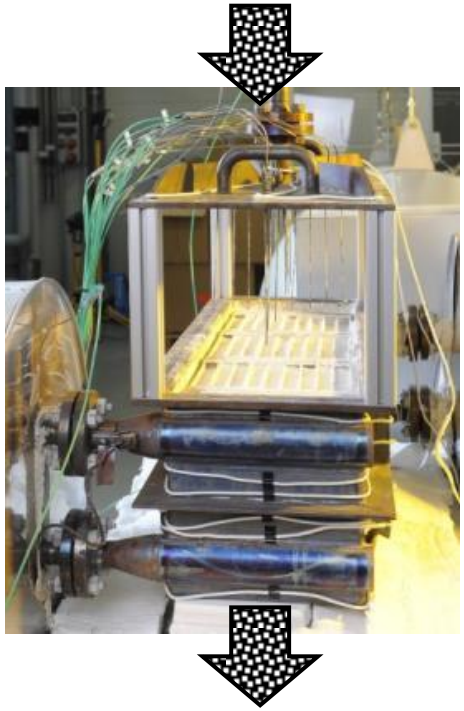


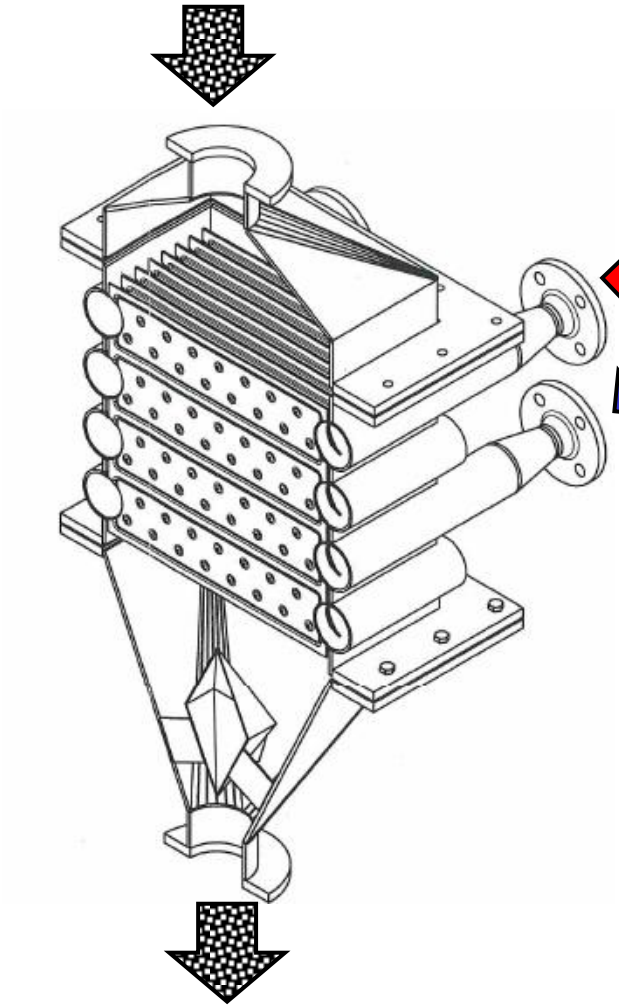
=> enhanced flowability

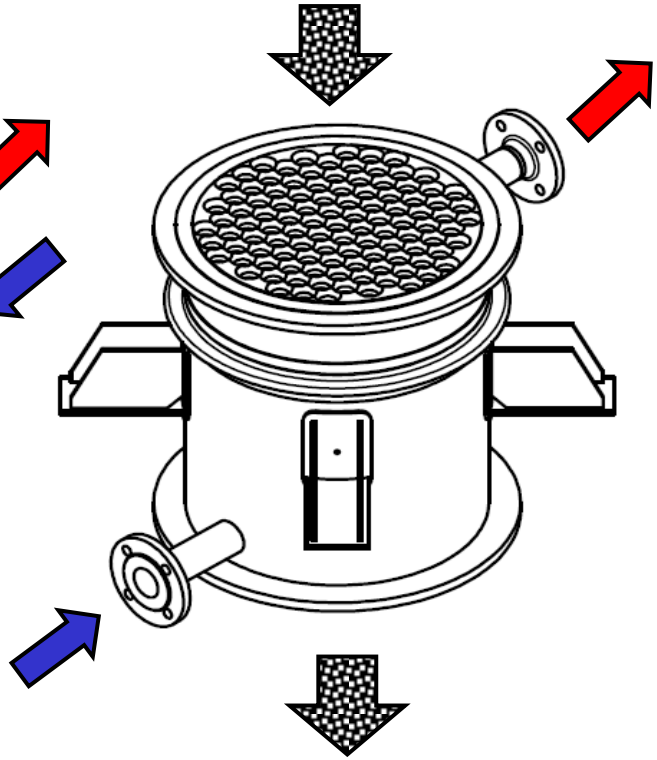
=> gravity assisted moving bed seems possible

Roßkopf et al. Improving powder bed properties for thermochemical storage by adding nanoparticles; Energy Conversion and Management 2014

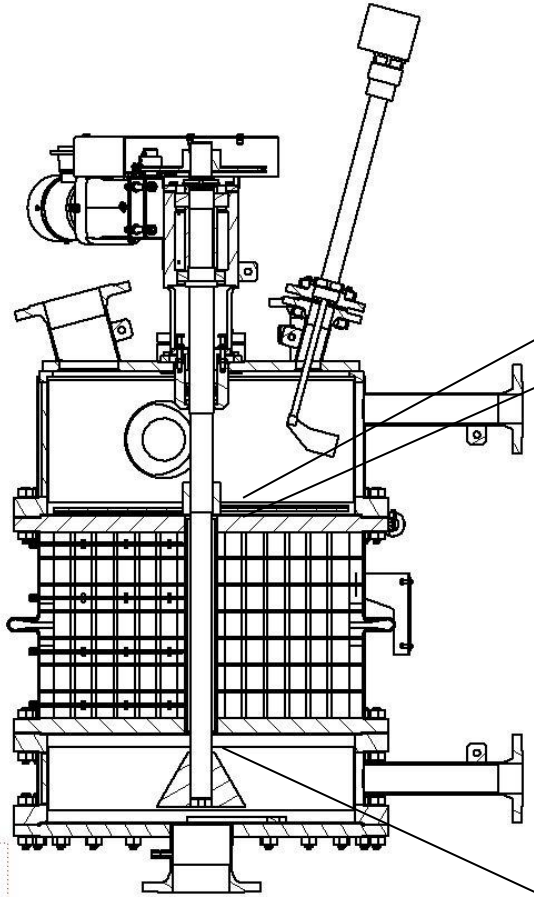
Assessment of reactor geometries

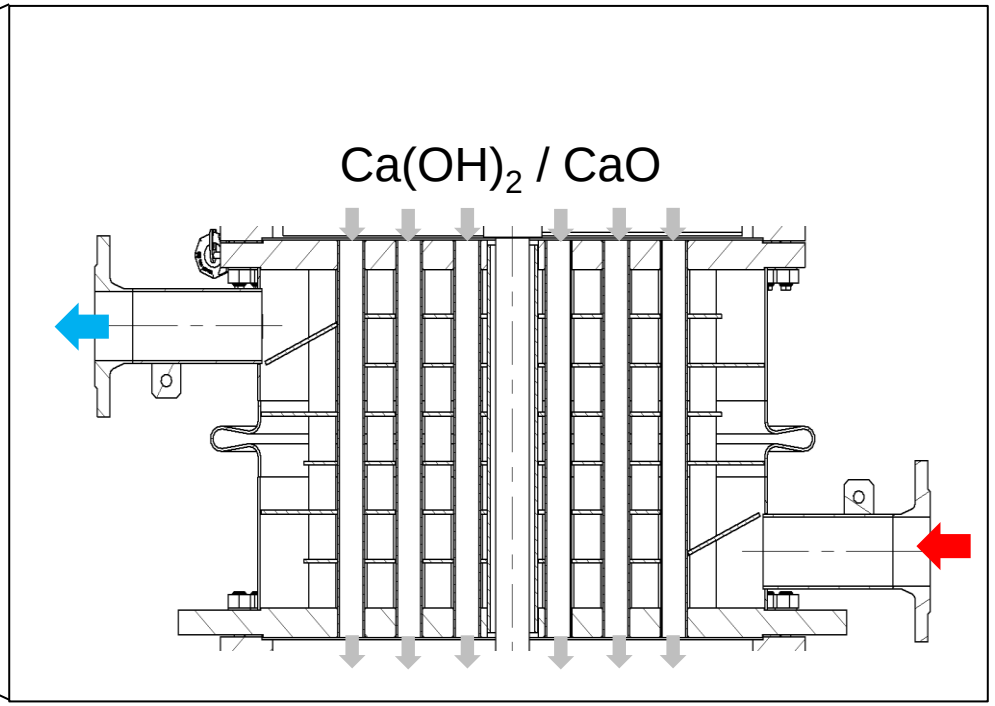




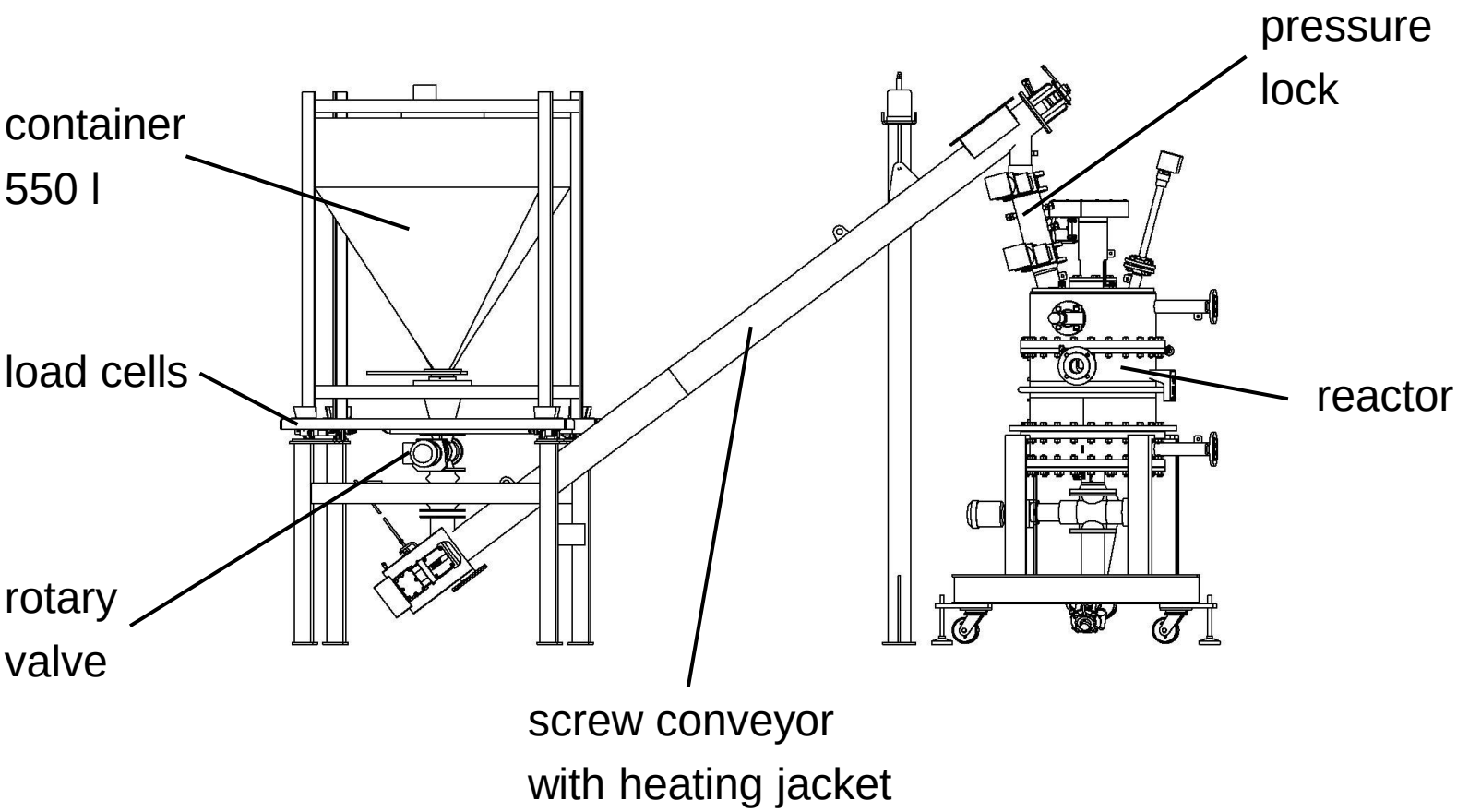


Final design of moving bed reactor

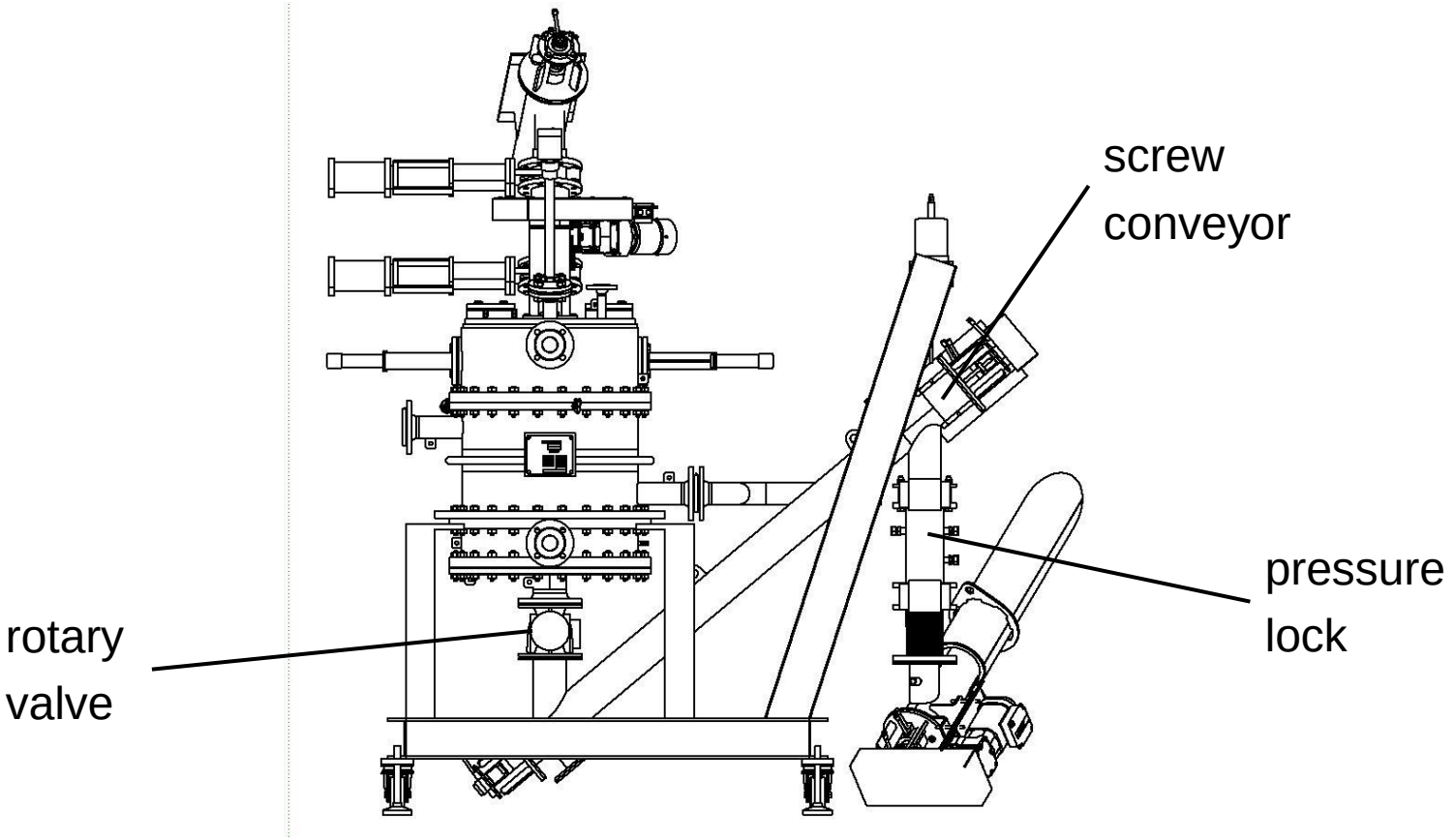




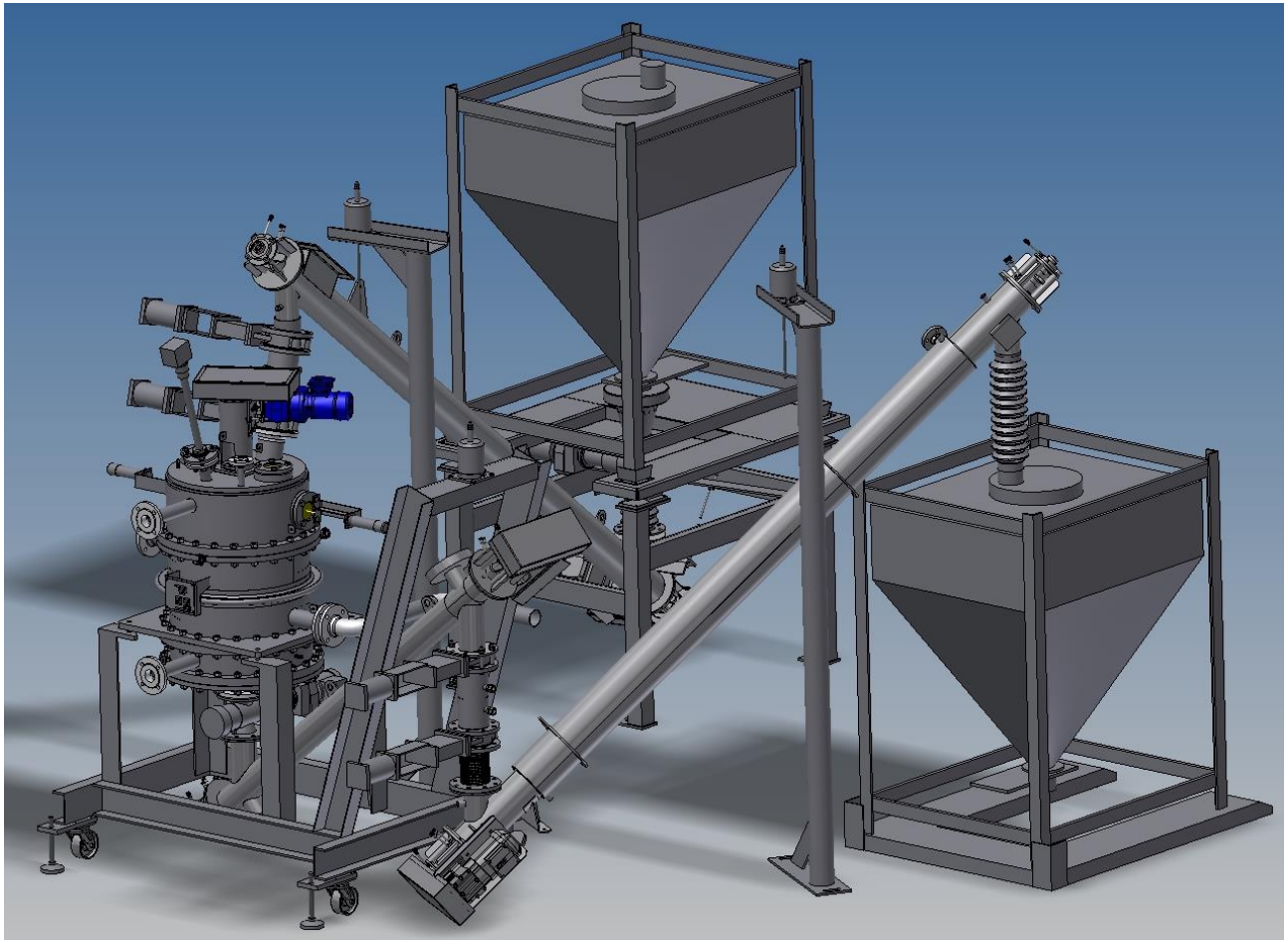
Conveyance of material to reactor inlet



Conveyance of reacted material from reactor outlet



Overall pilot plant design



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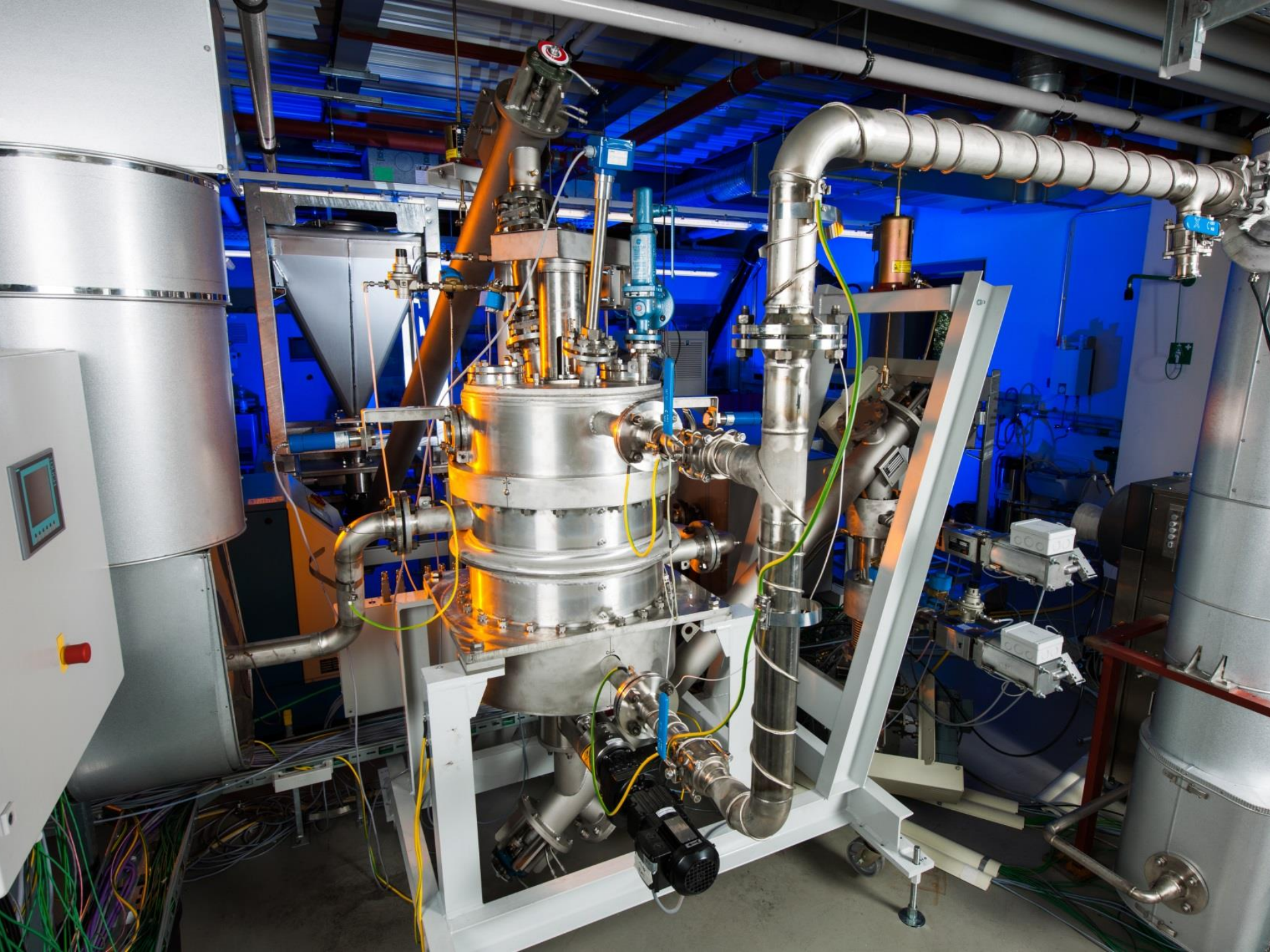
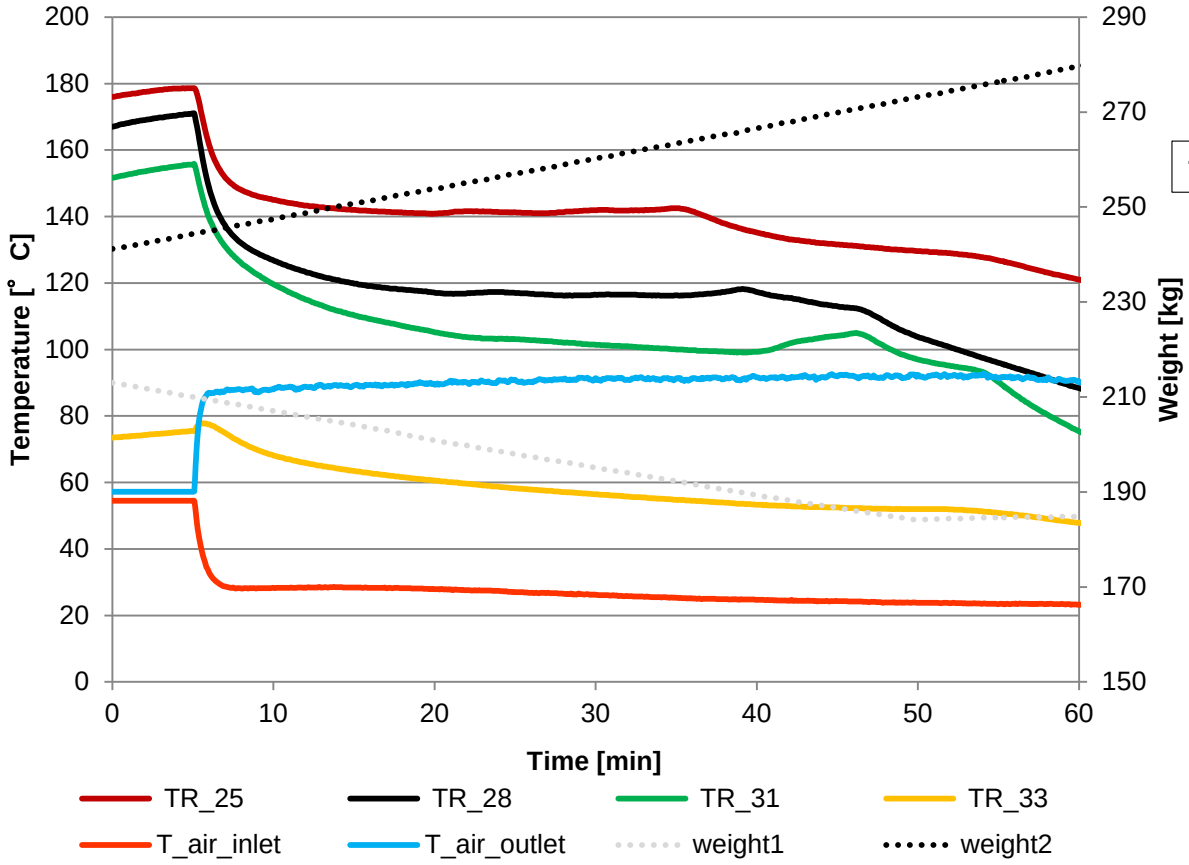
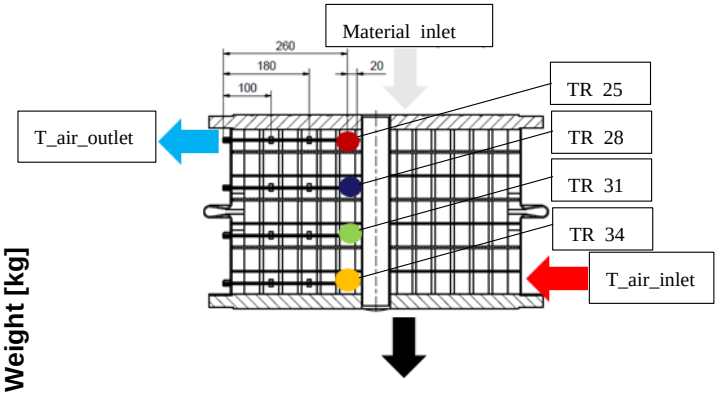
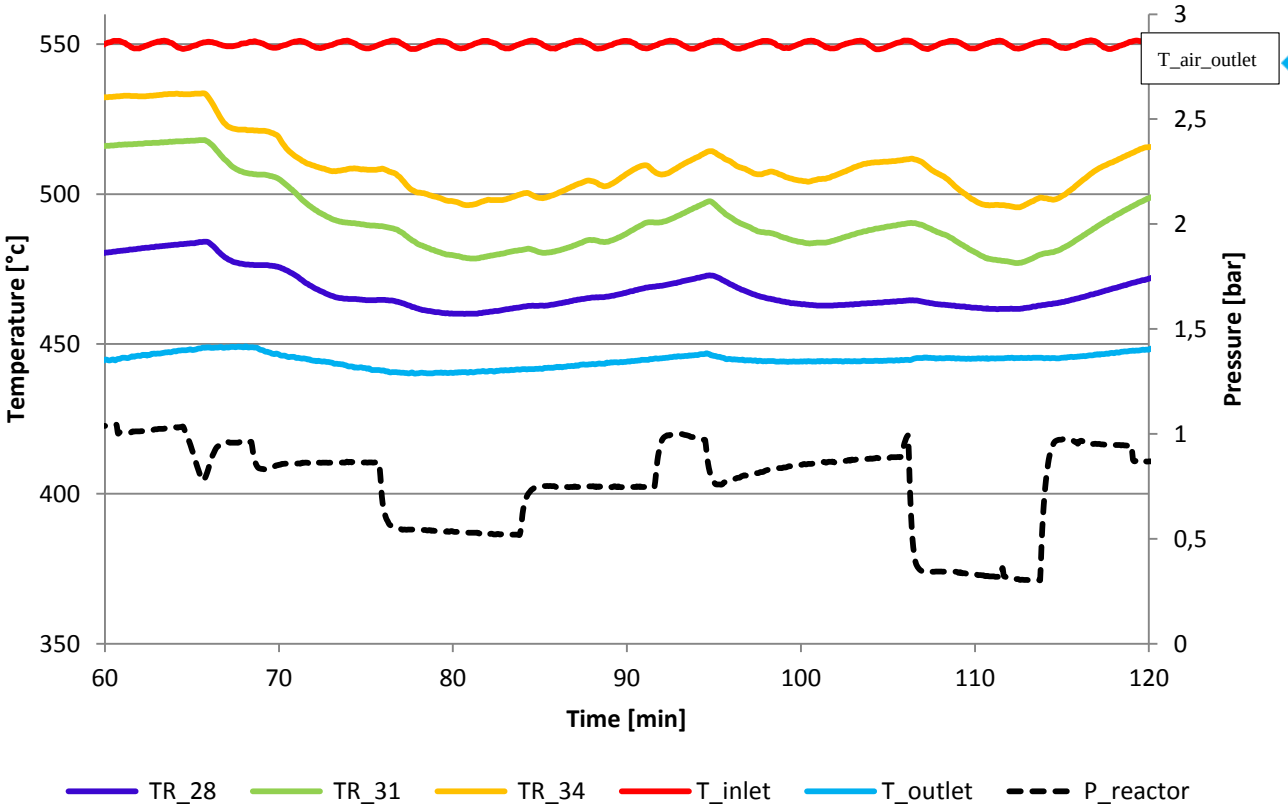


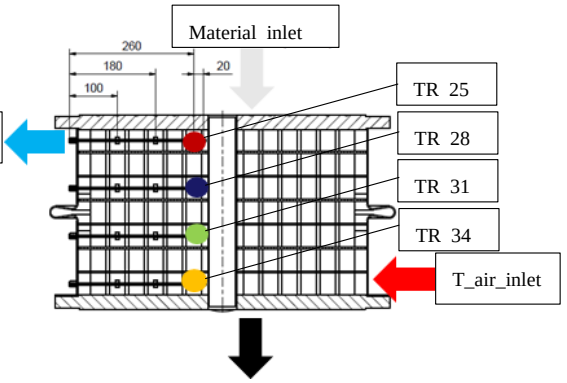
Heat extraction of moving particles

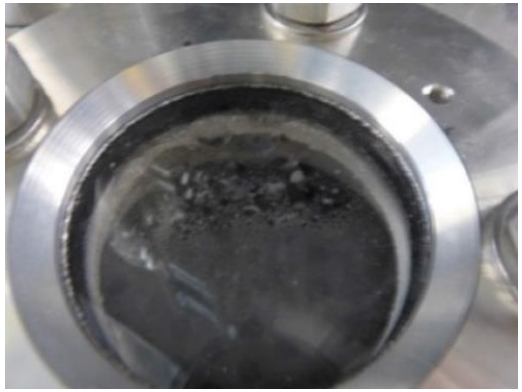




Current challenge…
Moving bed under reaction conditions







Summary

- $Ca(OH)_2$ offers low cost storage capacity
- Fixed bed is working but upscaling is economically not viable
- Material improvements focused on flowabilty of fine powder
- Commissioning in first experiments on 10 kW/100 kWh realized
- Extracted sensible heat from the moving particles
- Performed dehydration reaction

Current work:

=> Optimization of plant operation

=> Operation at different charging and discharging temperatures

=> Possibility to utilize sensible heat

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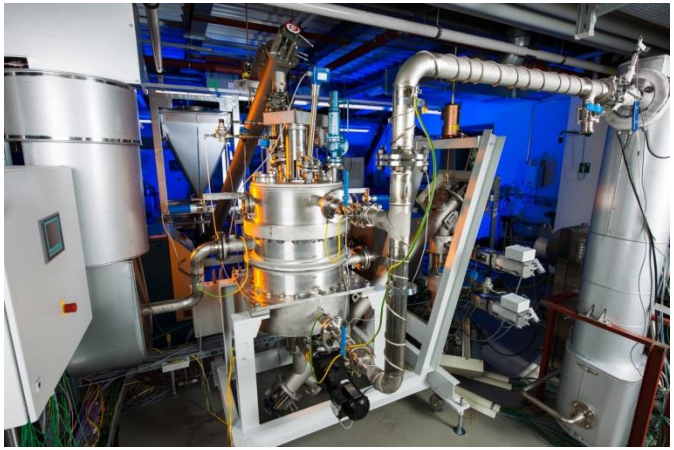

TCS Power
thermochemical energy storage

SEVENTH FRAMEWORK PROGRAMME

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